Optimizing the visualization of cervical spinal nerve roots by using three dimensional Double Inversion Recovery SPACE at 3-Tesla during MRI

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Aims and objectives

MR Neurography has been increasingly used to evaluate cases of suspected or established brachial plexopathy and peripheral neuropathy, with emphasis on three dimensional (3D) imaging [1-6].

3D-sampling perfection with application optimized contrasts using different flip angle evolution (SPACE) with STIR (STIR-SPACE) sequence has been reported as effective for visualizing the cervical spinal nerve roots and peripheral nerves [7,8]. STIR-SPACE sequence also obtains the cerebrospinal fluid (CSF) signal and the blood flow signal both of which have a possibility of getting in the way of making the diagnosis.

Double Inversion Recovery (DIR) sequence can suppress different types of tissues. There has been an interest in DIR parameter adjustments to highlight certain types of brain lesions [9-11]. However, to our knowledge, there are no studies applying DIR sequence to MR imaging of the cervical nerve roots. We predicted that DIR-SPACE sequence would have the potential to provide improved nerve-to-background tissue contrast compared to STIR-SPACE sequence which is currently used as a reference standard by suppressing both fat signal and cerebrospinal fluid (CSF) signal. In order to apply the 3D-SPACE with DIR (DIR-SPACE) sequence to visualize cervical nerve roots, it is necessary to adjust the DIR parameters.

The purpose of this study was to optimize nerve-to-background tissue contrast using DIR-SPACE sequence. And we compared the images obtained from optimized DIR-SPACE sequence with the images obtained from STIR-SPACE sequence generally used in clinical examination.

Methods and materials

MR Imaging

The study was performed on a 3.0-Tesla MR scanner (MAGNETOM Skyra; SIEMENS) using the 20-element head-neck receiver coil, 18-element phased array body receiver coil, and 32-element spine receiver coil.

Both DIR-SPACE and STIR-SPACE images were acquired for the cervical spine on the following same geometrical parameters (oblique coronal direction, field of view: 280 mm, slice thickness: 1.2 mm, band width: 560 Hz/pixel) and parallel imaging technique was
not used. The images were taken of a group of 9 normal subjects which included 5 males and 4 females under an IRB-approval. All images were acquired at an effective TE of 71 ms to exploit differences in $T_2$ between nerve and background tissue.

In DIR-SPACE sequence, the DIR pulses use both a non-selective IR pulse to suppress the CSF signal and another IR pulse to suppress the fat signal. The $T_1$ and $T_2$ values were (4200, 2000) ms for CSF [9], and (450, 52.96) ms for fat [12]. We consulted a reference [13] and configured the repetition time (TR) to 6000 ms and the second inversion time (TI2) to 240 ms to suppress the fat signal. And the first inversion time (TI1) was varied between 2200 ms and 3500 ms. Both inversion times TI1 and TI2 in DIR sequence represent the interval between the respective 180-degree inversion pulse and the 90-degree excitation pulse, which means that the two inversion pulses are separated by TI1 and TI2.

In STIR-SPACE sequence, we configured the parameter of the TR to 2000 ms which is generally used during clinical examination. And we set the inversion time (TI) to 220 ms which was determined by prior experimentation on several volunteers as being the best parameter setting for suppressing the fat signal.

**Image Analysis**

The signal intensity (SI) measurements were obtained using the region-of-interest analysis. The regions were placed in the following tissues; nerve, CSF, Fat, and muscle as shown in Fig. 1.
The contrast-to-noise ratios (CNR) of the DIR-SPACE sequence were determined from the respective mean values of the contrast between nerve and CSF, nerve and fat, nerve and muscle. The CNR was defined by the following formula:

\[
\sqrt{\frac{\pi}{2}} \cdot \frac{|SI_1 - SI_2|}{SI_{BG}}
\]

**Fig. 2**


where \(SI_1\) is the signal intensity of the nerve and \(SI_2\) is the signal intensity of the CSF, fat, or muscle, respectively, \(SI_{BG}\) is the signal intensity of the background area shown in Fig. 1.
Next, we made a comparative review of the difference between the optimized DIR-SPACE sequence and the STIR-SPACE sequence. We compared the signal intensity of nerve, CSF, and fat, respectively.

Images for this section:

![Fig. 1: the regions-of-interest](image)

\[ \sqrt{\frac{\pi}{2}} \cdot \frac{|SI_1 - SI_2|}{SI_{BG}} \]

Fig. 2
Results

Figure 3 shows the results of signal intensity measurements. As the TI1 became longer, both nerve and CSF signals became increasingly higher. Both fat and muscle signals showed constancy.

![Graph showing the relationship between TI1 and signal intensity.](image)

*Fig. 3:* The relationship between TI1 and signal intensity.

**References:** Department of Radiological technology, Yamaguchi university hospital - Ube City/JP

Figure 4 shows the results of CNR measurements. As the TI1 became longer, the nerve-to-fat CNR and nerve-to-muscle CNR became increasingly higher. The nerve-to-CSF CNR showed constancy until the TI1 reached 3000 ms. When the value of TI1 was longer than 3000 ms, the nerve-to-CSF CNR decreased significantly. Figure 5 shows examples of the DIR-SPACE images with varied TI1 parameters. From our results, we found that the optimized TI1 was 3000 ms when the TI2 was configured at 240 ms.
Fig. 4: The relationship between TI1 and CNR.

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Fig. 5: The coronal images of the cervical spine. The arrows point to the CSF signal. All images are of the same window setting. It would be assumed that the decrease of nerve-to-CSF CNR was strongly affected by the increase of the signal intensity of the CSF.
Both Fig. 6 and Fig. 7 show examples of the optimized DIR-SPACE images (TI1: 3000 ms, TI2: 240 ms) and the STIR-SPACE images (TI: 220 ms). Compared to the STIR-SPACE sequence, the DIR-SPACE sequence had a beneficial effect on both suppressing CSF signal (Fig. 6) and eliminating blood-flow artifact (Fig. 7).

**Fig. 6**: Coronal images of the cervical spine. DIR-SPACE images showed lower signal intensity of CSF than STIR-SPACE images.

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Fig. 7: Coronal images of the cervical spine. DIR-SPACE images showed a higher suppressing effect of blood flow artifacts than STIR-SPACE images.

References: Department of Radiological technology, Yamaguchi university hospital - Ube City/JP

Images for this section:
Fig. 3: The relationship between TI1 and signal intensity.
**Fig. 4:** The relationship between TI1 and CNR.

**Fig. 5:** The coronal images of the cervical spine. The arrows point to the CSF signal. All images are of the same window setting. It would be assumed that the decrease of nerve-to-CSF CNR was strongly affected by the increase of the signal intensity of the CSF.
Fig. 6: Coronal images of the cervical spine. DIR-SPACE images showed lower signal intensity of CSF than STIR-SPACE images.
**Fig. 7:** Coronal images of the cervical spine. DIR-SPACE images showed a higher suppressing effect of blood flow artifacts than STIR-SPACE images.
Conclusion

Our results showed DIR-SPACE with optimized T11 parameter settings has the potential to obtain high contrast images of cervical nerve roots by suppressing background tissues.

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